Running injuries: a radiologist perspective

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Learning objectives

Running is an increasingly popular form of exercise in our society. Running is widely known to be beneficial for general health, but of the consequences of running is running-related injuries, whose incidences rates are raising. Therefore more MR imaging examinations are performed.

Although evaluation of patients with potential running-injuries relies on clinical exploration, imaging plays an essential role in the identification of abnormalities, and it helps for the correct diagnoses and to initiate appropriate treatment.

There are some injuries to look out for running players. We review and illustrate the most frequent injuries. These injuries include: muscular strain and tendinopathy, bone stress lesions (the most common: shin splints), iliotibial band syndrome or plantar fasciitis (Image 1)

The aim is to provide a general review of MRI manifestations of the wide spectrum of injuries that running can cause. Precise knowledge and accurate reporting of the findings are useful for clinical decision and management of these patients.
Fig. 1

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Background

Because of its easily accessibility, running is practised by many people. Besides its positive health effects, running may also cause injuries, especially to the lower extremities.

The aim of this poster is to provide a general review of MRI manifestations of the wide spectrum of injuries that running can cause.

Various studies have reported that the incidence of lower extremity running injuries ranged from 20% to 79% and the knee was the predominant site of these injuries, followed by the lower leg, the foot and the upper leg.

It is important to notice that a history of previous injuries is a risk factor for runners.

Although the most common site of lower extremity running injuries is the knee, we review and illustrated other common and frequent injuries as iliotibial band friction syndrome, plantar fasciitis or Achilles tendinopathy.

1. BONE STRESS LESIONS

Fatigue stress fractures are common in young runners when there is a continuous repetitive strain on the bones. Fatigue fractures occurs in normal healthy bones because of abnormal muscular stress instead of insufficiency fractures that occurs in unhealthy bone (most common in elderly and postmenopausal women).

The incidence of stress fracture approaches 16% in runners.

Patients typically present with localized pain without history of trauma.

Although conventional radiographs are the first line management of a suspected stress fracture, MRI is the gold standard for imaging of stress fractures.

In the diagnosis, follow-up and management it is very important to distinguish stress injury/stress response from a stress fracture:

- **STRESS RESPONSE**: is the first stage in the development os a stress fracture. MRI is the gold standar and the more sensitive technique in the detection of stress injury.

The earliest sign is shown on MRI as poorly defined abnormal signal intensity of the bone marrow (hypointense on T1-weighted sequences and hyperintense on STIR or T2-WI fat-suppression). No fracture line is seen Fig. 2 on page 9
There are 2 typical forms of stress injuries in runners which may result in fracture if the stress continues: thigh splints and shin splints:

1. **THIGH SPLINTS (ADDUCTOR INSERTION AVULSION SYNDROME)** is a stress injury usually found in runners. Patients present with hip, groin or thigh activity related pain.
   - **Key clue**: abnormal high signal intensity along the periosteum of the posteromedial aspect of the proximal femur at the side of the adductor insertion.

2. **SHIN SPLINTS (MEDIAL TIBIAL STRESS SYNDROME)** is another form of stress injury at the posteromedial aspect of the tibia. The anterior cortex is most commonly affected.
   - **Key clue**: periosteal reaction with surrounding soft tissue edema Fig. 3 on page 9 Fig. 4 on page 10 Fig. 5 on page 11 Fig. 6 on page 12

**STRESS FRACTURE**: if the repetitive activity continues a stress fracture can develop and marrow changes may become more evident.

   - **Key clue**: an irregular hypointense line with surrounding edema Fig. 7 on page 13 Fig. 8 on page 14

Periosteal callus formation begins shortly after the fracture occurs. As the changes become more chronic, there is cortical thickening and irregularity.

Stress injuries were also graded according to the *classification proposed by Fredereicsson et al into 4 grades* that describe the continuum of MRI findings of osseous stress injury.

   - **Grade 1**: periosteal edema without focal bone marrow abnormality
   - **Grade 2**: more severe periosteal edema with bone marrow edema detected on T2-WI only
   - **Grade 3**: moderate to severe edema of both the periosteum and marrow on both T1 and T2 WI.
   - **Grade 4**: a low signal fracture line on all sequences with changes of severe marrow edema in both T1 and T2-WI sequences Fig. 9 on page 15

In runners, the most commonly affected bone is the **TIBIA** (the proximal third), representing approximately 40% of stress fractures, followed by the fibula. The 55% of stress fractures of the foot and ankle occur in the **metatarsals** (the second and third metatarsal are the most common affected).
Femoral and tarsal fractures occur in older runners whereas in youngest population tibial and fibular fractures are more common. Medial malleolar stress fractures and calcaneal stress fractures typically present in runners and are related to repeated compression from heel strikes and tug forces from the Achilles tendon. Navicular stress fractures usually affects runners and are often difficult to diagnose on conventional radiographs in a patient that complain of dorsal pain in midfoot.

Runners are also prone to pubic rami and sacral stress fractures, particularly when there is an increase in impact activity due to a more vigorous training program.

**2. METATARSALGIA**: could be cause by metatarsal stress reaction and sesamoiditis.

The second and third metatarsal are the most vulnerable to stress injuries. The fracture is typically in the dyaphisis.

These fractures should be suspected when activity-related foot pain occurs in an initial runner or in significant change in activity, including a change of shoes or running surface.

- Key clue: diaphyseal fracture with hyperintense marrow edema and soft tissue reaction Fig. 7 on page 13

Sesamoid injuries: sesamoids are prone to injury with overuse, especially in repetitive high impact sports such as running.

Runners with sesamoid pathology present with vague metatarsal pain, exacerbated by passive dorsiflexion of the MTP joint.

Sesamoid disorders include bipartite sesamoids, stress fractures, acute fracture, turf toe, avascular necrosis, sesamoiditis, arthritis and bursitis.

- Key clue: altered signal intensity or morphology of sesamoids Fig. 10 on page 16

It is also important to consider in a runner with ankle pain the possibility of osteochondral fractures. Osteochondral fractures have been reported in long distant runners because following repetitive impact trauma to the talar dome Fig. 11 on page 17

**3. ILIOTIBIAL TRACT FRICTION SYNDROME (RUNNER’S KNEE) OR ILIOTIBIAL BAND SYNDROME (ITBS):**

It is a common condition seen in runners and is due to impingement of the band against the lateral aspect of the lateral femoral condyle. ITBS accounts for 12% of running-related overuse injuries.

These patients present with focal lateral pain on running.
It is best appreciated on coronal fat suppressed images.

- **Key clue:** increased signal intensity within soft tissues interposed between the iliotibial band and the lateral condyle on T2-WI Fig. 12 on page 18 Fig. 13 on page 19
- **Differential diagnosis:** lateral meniscal tear and lateral collateral ligament injury.

4. PLANTAR FASCIITIS

It is usually an overuse injury and it is the most common cause of *heel pain in runners*. Some risk factors are increased intensity, increased running distance or change in running surface.

Although the diagnosis is usually based on clinical history and physical examination, imaging is necessary to differentiate plantar fasciitis from calcaneal stress fracture. MRI findings:

- **Fasciitis:** thickened medial plantar aponeurosis (7-8mm) with perifascial soft tissue edema Fig. 14 on page 20. It could be plantar aponeurosis hyperintensity on T2-WI, hyperintense subcutaneous tissue edema or deep to the fascia, or reactive calcaneal marrow edema.
- **Partial and complete tears:** discontinuity of some or all the fibers with loss of the normally low signal intensity on T1-WI. In complete rupture: hyperintense fluid-filled gap Fig. 15 on page 21

5. PATELLOFEMORAL PAIN SYNDROME

Patellar femoral pain syndrome is the most common overuse running injury. The underlying pathology may be chondromalacia or clinically occult patellar malalignment

**Meniscal injuries** are also important to consider in runners because there is very common degenerative changes in meniscus with prolonged years of running. Meniscal tears are most common in the posterior horn of the medial meniscus

6. MUSCLE INJURIES

The most commonly strained muscles in the extremities are the rectus femoris, hamstrings and gastrocnemius muscles Fig. 16 on page 22 Fig. 17 on page 23 Fig. 18 on page 24

Muscles injuries could be classified into 3 grades:
• **MILD INJURY (1° DEGREE STRAIN):** hyperintense edema (subcutaneous tissue edema or intermuscular fluid) with preservation of muscle morphology.

• **MODERATE INJURY (2° DEGREE STRAIN):** it is a partial thickness tear. Most of these strains resolve clinically in 2 weeks, although some of these injuries are associated with persistent pain and increased susceptibility to recurrent strain. **Key clue:** hyperintense focal defect with partial retraction of muscle fibers.

• **SEVERE INJURY (3° DEGREE STRAIN):** It is a complete musculotendinous disruption. A hematoma is often seen in the gap created by an acute tear. **Key clue:** hyperintense fluid filled gap Fig. 19 on page 25

The *hamstrings muscles* are the most commonly injured in sprinting. In runners the most common isolated muscular strain affects is the medial head of the *gastrocnemius muscle*.

7. **TENDON INJURIES:**

Tendon injuries commonly occur as the result of overuse in running and include chronic degeneration, partial or complete tears.

Typical sites of injury in runners: *flexor hallucis and flexor digitorum longus, peroneal tendon, patellar tendon and Achilles tendon.*

Running have a high incidence of Achilles tendon overuse injuries. **Achilles tendon injuries** account for approximately 7% of running injuries and occur more commonly in males.

- Achilles tendinopathy: focal thickening/convex anterior shape or diffusely enlarged tendon Fig. 20 on page 26
- Partial tears: tend to occur in an area of tendinosis
- Rupture: it is usually diagnosed clinically and imaging help to determinate the extent of injury and treatment planning. **Key clue:** hyperintense fluid-filled tendinous gap and retraction. Rupture occurs 2-6cm superior to the calcaneal insertion Fig. 21 on page 27

**PATELLAR TENDINOSIS:** most commonly affects the proximal posterior fibers.

- **Key clue:** patellar tendon thickening+/- partial or complete tearing and edema Fig. 22 on page 28
Fig. 2: Stress response

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**SHIN SPLINT**

_Axial and coronal MR images in a 25 year-old runner with pain_

Axial and coronal fat supressed T2-WI MRI show bone marrow edema

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**Fig. 3: SHIN SPLINTS**

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Fig. 4: SHIN SPLINTS

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Notice the bone marrow edema in the anteromedial region of the tibia (axial and sagittal fat supressed T2-WI MRI and diffusion MR images)
Axial and coronal fat supressed T2-WI MRI show hyperintense anteromedial periosteal edema with posteromedial extension and bone marrow edema.

**Fig. 5:** SHIN SPLINTS

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**SHIN SPLINT**

A 30 year-old runner with pain without history of trauma

Axial fat supressed T2-WI MR images demonstrate hyperintense periosteal edema along the anteromedial aspect of the tibia with posteromedial extension

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**Fig. 6: SHIN SPLINTS**

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Axial and coronal T2-WI fat suppressed MR image show hyperintense bone marrow edema in second metatarsal stress fracture and soft tissue reaction

**Fig. 7: STRESS FRACTURE**

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**STRESS FRACTURE**

*A 35 year-old runner with pain over the distal tibia increasing over several weeks*

Sagittal and coronal T1 and T2 WI MRI demonstrate horizontal low signal fracture line (yellow arrow). The findings are in keeping with a grade 4 stress fracture

Fig. 8: STRESS FRACTURE

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Fig. 9: METATARSAL FRACTURE

A 22 year-old man with foot pain when running. MRI was performed.

Sagittal T1 and axial and sagittal T2-WI fat suppressed MR images of the second metatarsal show extensive bone marrow edema. There are adjacent soft tissue edema and a low signal fracture line (yellow arrow). Example of a grade 4 stress fracture.
Coronal and axial T2 fat suppressed WI-MRI show high signal intensity in medial bipartite sesamoid with slight surrounding soft tissue edema

**Fig. 10: SESAMOID DISORDERS**

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OSTEOCHONDRAL DEFECTS OF THE TALUS

Coronal and axial T2-WI fat suppressed MRI demonstrate a round area of high signal intensity within the medial talar dome (yellow arrow).

Fig. 11: OSTEOCHONDRAL LESIONS

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Coronal and axial fat suppressed T2-WI show high signal deep and surrounding the iliotibial band. The lateral meniscus was normal.
**Fig. 13:** ILIOTIBIAL BAND SYNDROME

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**ILIOTIBIAL BAND SYNDROME OR ILIOTIBIAL TRACT FRICTION SYNDROME**

Coronal and axial fat supressed T2-WI show increased signal intensity within soft tissue interposed between the iliotibial band and the lateral condyle.

Notice that these changes are best appreciated on coronal fat supressed images.
Sagittal T2-WI fat supressed MR image shows thickening of the apponeurosis with adjacent inflammatory changes and calcaneal subchondral marrow edema. Notice also the bone marrow edema in the talus.

**Fig. 14:** PLANTAR FASCIITIS

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Sagittal and coronal T2-WI fat suppressed MRI reveal focal thickening of proximal plantar fascia with surrounding soft tissue edema and subchondral marrow edema in the calcaneal. Notice the discontinuity and high signal intensity in some of the fibers of the fascia.

**Fig. 15: PARTIAL TEAR**

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Fig. 16: MUSCLES INJURIES

Axial and coronal T2-WI MR images show high signal intensity (edema) within soleus muscles.
Fig. 17: MUSCLES INJURIES

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**Fig. 18: MUSCLES INJURIES**

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**MUSCLE INJURIES: STRAIN**

Axial and coronal T2-WI MR images show diffuse hyperintense edema involving the medial aspects of the soleus muscle.
Fig. 19: MUSCLES INJURIES

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Fig. 20: ACHILLES TENDINOPATHY

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Fig. 21: TENDON INJURIES

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Sagittal and axial T2-WI fat suppressed MRI show a discontinuity and retraction of the tendon (yellow arrow). Notice the hyperintense fluid-filled tendinous gap in the axial images.
Axial, coronal and sagittal fat suppressed T2-WI MRI show high signal intensity within patellar tendon with discontinuity of some of the fibers. Minimal partial tear was suspected.

**Fig. 22: PATELLAR TENDINOSIS**

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Findings and procedure details

Although there are other useful imaging techniques as ultrasound, this poster focuses on MRI as the imaging test of choice for evaluating running-related injuries.

A 1.5 tesla MRI is used to perform exams. MRI examination include at least two orthogonal planes and pulses sequences. T1-WI and an edema-sensitive sequence such as short tau inversion recovery (STIR) or T2 with frequency-selective fat suppresion are used. The STIR or fat supressed T2 sequences are important for detection of edema.
Conclusion

• Running is an increasingly popular form of exercise in our society but one of the consequences of running is running-related injuries, whose incidences rates are raising.
• Imaging plays an essential role in the identification of abnormalities. Precise knowledge and accurate reporting of these findings are useful for clinical decision and management of these patients
• There are some injuries to look out for running players: muscular strain and tendinopathy (Achilles tendon), bone stress lesions (the most common: shin splints), iliotibial band syndrome or plantar fasciitis.
• Running related bone injuries are most often due to overuse. Exercise induced stress reaction involving the tibia are common. Early detection of tibial stress injuries may be crucial to prevent stress fracture and complications.
References